



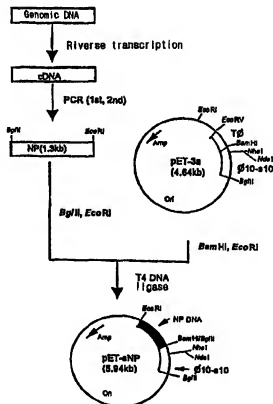
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(54) Title: NUCLEOCAPSID GENE OF SEOUL VIRUS R22, RECOMBINANT PLASMID, TRANSFORMED E. COLI AND DIAGNOSTIC AGENT AND VACCINE FOR HAEMORRHAGIC FEVER WITH RENAL SYNDROME

(57) Abstract

The present invention relates to a nucleocapsid gene of Seoul virus R22 strain, a recombinant expression vector for the said gene, a transformed microorganism with the said recombinant plasmid and a nucleocapsid protein expressed by the said transformant, as well as a novel pharmaceutical composition for diagnosis or prevention of haemorrhagic fever with renal syndrome caused by viruses in the *Hantavirus* genus containing the said nucleocapsid protein.



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**NUCLEOCAPSID GENE OF SEOUL VIRUS R22,
RECOMBINANT PLASMID, TRANSFORMED E. COLI AND
DIAGNOSTIC AGENT AND VACCINE FOR HAEMORRHAGIC
FEVER WITH RENAL SYNDROME**

5

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

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The present invention relates to a novel pharmaceutical composition for diagnosis or prevention of haemorrhagic fever with renal syndrome caused by viruses in the *Hantavirus* genus, as well as a nucleocapsid gene of Seoul virus R22 strain, a recombinant expression vector for the said gene, a transformed microorganism with the said recombinant plasmid and a nucleocapsid protein expressed by the said transformant.

15

DESCRIPTION OF THE PRIOR ART

20

It has been reported that there are more than ten serologically distinct hantaviruses in the *Hantavirus* genus of the family *Bunyaviridae*. Hantaan virus or Seoul virus among such hantaviruses are known as the major aetiological agents of haemorrhagic fever with renal syndrome (HFRS) in Korea. The two viruses contain a tripartite, single-stranded, negative-sense RNA species (S, M and L segments) in common. The S, M and L genome segments encode nucleocapsid protein, glycoproteins G1 and G2, and RNA polymerase, respectively. The nucleocapsid protein and the glycoproteins G1 and G2 are implicated in an immunoreaction.

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To develop effective diagnostic agent and vaccines for HFRS, extensive

studies have been performed by using viruses *per se* and proteins implicated in the HFRS immunoreaction. Since the primary condition of HFRS seems to be a cold and the symptoms of HFRS are substantially similar to those suffering from the disease caused by *Leptospira* or *Rickettsia*, it is difficult to accurately diagnose the HFRS with clinical observations. The treatment of HFRS at the primary conditions would prevent such condition from turning fatal. Therefore, it is necessary to make a correct diagnosis of HFRS at the primary conditions.

The correct diagnosis of HFRS can be accomplished by using serological tests. In this assay, blood is collected from a patient twice a week and an increase of titres of anti-hantavirus antibodies is observed by indirect immunofluorescence technique or plaque reduction of neutralization antibody assay. The serological tests are accurate but require at least 7 days. Moreover, these assays are accompanied by cumbersome cell culture.

Many studies have been made to develop alternative diagnostic means of HFRS, while shortening the requirement time for diagnosis and avoiding the cumbersome process of the cell culture. Such studies are focused on the production of viral antigens which react with the anti-hantavirus antibodies in the patient blood. Nucleocapsid protein or G1 or G2 glycoproteins might be considered as the hantavirus antigen for diagnosis of HFRS. The nucleocapsid protein acts as a major antigen at the beginning of the hantavirus infection and induces a large quantity of antibodies in HFRS patients. The antibodies to the nucleocapsid protein are retained for a short duration. In this regard, the nucleocapsid protein are proper as an antigen for diagnosis of HFRS. In contrast, since the antibodies to G1 or G2 glycoproteins can be retained for many years, they are inappropriate as being indicative of the diagnosis of acute HFRS patients.

30

Commercially available antigens used as a diagnostic agent for HFRS are produced through cell culture or enrichment of the hantavirus on mouse brain. However, such cell culture or enrichment requires high costs and have resulted in low yields as well as high danger of viral infections among laboratory workers and animal handlers. Under the circumstances, there have been many studies to massively produce the hantavirus nucleocapsid protein through genetically recombinant technology.

Schmaljohn, etc. of *J. Gen. Virol.* (1988), 69, 777-786 suggested expression of the nucleocapsid gene of Hantaan virus in insect cells through baculovirus expression system and potential use of the expressed nucleocapsid protein as a diagnostic antigen for HFRS. However, the expressed amount of the nucleocapsid protein is insufficient.

Wang, etc. of *J. Gen. Virol.* (1993), 74, 1115-1124 and Gott, etc. of *Virus Res.* (1991), 19, 1-16 reported *E. coli* expression of the nucleocapsid gene of Hantaan virus and potential use of the expressed nucleocapsid protein for diagnosis of HFRS. However, their methods are disadvantageous because of low yield and insufficient purity. Another disadvantage is that the expressed nucleocapsid protein is generated as inclusion body.

It is commonly known that viral vaccines made from attenuated or inactivated whole virus are relatively effective. However, there are several problems in the production of vaccines using attenuated or inactivated virus. First, cultivation of the virus is usually inconvenient, accompanying cell culture. Second, it is difficult to isolate and purify the virus from cultures in high purity. Third, the possibility to obtain the intact virus is very low because the most of virus is destroyed during purification process. Fourth, the attenuation or inactivation of the purified virus for vaccine are conventionally achieved by formalin treatment or heating. This procedure might lead to denaturation of the

vaccine. Fifth, such vaccines are defective in safety which becomes the most considerable factor in production of vaccines.

5 A first generation vaccine for Hantaan virus has been prepared by using the isolated virus from cerebral fluid of mouse following cultivation of the virus on the mouse brain. However, it is impossible to completely remove the basic myelin protein which is known to cause certain side effect, from the cerebral fluid of mouse. Furthermore, a trace of unidentified proteins derived from mouse brain may exist in the vaccine and as a result, doubts on the
10 safety of the vaccine can arise.

Many researchers have striven to develop cell free production system or *in vitro* expression system for preparation of the hantavirus antigenic proteins without hazardous proteins or substances. For instance, C. S. Schmaljohn, etc. elucidated nucleotide sequences and gene arrangements of M, S and L segment genomes of original Hantaan virus 76-118 and observed the preventive capability of Hamster against Hantaan virus following injection of the combined vaccinia gene with M segment encoding glycoproteins G1 and G2 into the animal body. They also reported that S segment encoding
15 nucleocapsid protein increases the preventive capability of glycoproteins. Further, They managed to express G1, G2 and nucleocapsid protein of Hantaan virus in insect cells using baculovirus and then addressed the vaccination of animal with the crushed insect cell lysates but failed to observe the formation of neutralization antibodies derived from the nucleocapsid protein
20 of Hantaan virus.

The nucleocapsid protein of hantavirus is a structural protein which is expressed from S segment of RNA of the virus and then exists as a complex with the RNA. Since the nucleocapsid protein constitutes most part of the
30 viral proteins, the purification of the nucleocapsid protein from virus cultures

is convenient. However, the studies on the induction of neutralization antibodies of the hantavirus nucleocapsid protein accomplished until now are only the use of vaccinia virus as the expression vector for the nucleocapsid gene and the administration of infected cell lysates including the expressed nucleocapsid protein into animal. The purely isolated nucleocapsid protein of hantavirus has never been applied for a study on the formation of neutralization antibodies and therefore nobody has perceived the hantavirus nucleocapsid protein to be a valuable vaccine for HFRS by generating neutralization antibodies.

Meanwhile, it is very difficult to purify the glycoproteins (G1 and G2) of Hantaan virus and other viruses of the Hantavirus genus and any genetic engineering methods have not made it possible to massively produce the glycoproteins in *E. coli*, yeast or animal cells.

Despite that many problems may occur when vaccine is prepared from virus *per se*, all of the currently available vaccines for the prevention of HFRS have been prepared by directly culturing the virus on mouse brain or animal cell and inactivating the purified virus from the cultures with formalin.

The inventors have intensively studied to develop a method which makes it possible to massively produce the antigen for diagnosis of HFRS while ensuring the enhanced safety, diminishing costs and eliminating the tedious and troublesome process of cell culture. The inventors now attained to elucidate the full nucleotide sequence of nucleocapsid gene of Seoul virus R22 and successfully developed a novel expression system capable of massively producing the Seoul virus R22 nucleocapsid protein in a fused form of protein having extra 14 amino acids at amino terminus in *E. coli* and a method for purifying the nucleocapsid protein. It was now found that the purified nucleocapsid protein produced by the inventors can be used as an active

material for the desired rapid, convenient, sensitive, safe HFRS diagnostic preparation. In addition to the use of the present nucleocapsid protein for diagnosis of HFRS patients, it was also found that the present nucleocapsid protein can be also used to determine the formation of antibodies in individuals inoculated with HFRS vaccines. This finding means that the use sphere of the present nucleocapsid protein in the diagnostic preparation for HFRS is wider than that of the current available diagnostic preparations.

The inventors also found that the present nucleocapsid protein of Seoul virus is very useful in the preparation of vaccine for HFRS caused by either Seoul virus or Hantaan virus. It was reported that the vaccine prepared by inactivating Seoul virus is capable of protecting individuals from even Hantaan virus, in addition to Seoul virus (Yamanishi, et al., Vaccine (1988), 6, 278-282). This report is why the inventors selectively used the nucleocapsid protein of Seoul virus in order to prepare vaccine for prevention of HFRS caused by both Seoul virus and Hantaan virus.

In addition, the inventors found that the vaccine prepared by using the present nucleocapsid protein is considerably superior over the current available vaccines in terms of its efficacy and safety.

SUMMARY OF THE INVENTION

The present invention provides a nucleocapsid gene of Seoul virus R22 having the following nucleotide sequence:

30

10 20 30 40 50
| | | | |
ATGGCAACTATGGAGGAAATCCAGAGAGAAATCAGTGCTCACGAGGGGCA

5 60 70 80 90 100
| | | | |
GCTTGTGATAGCACGCCAGAAAGTCAAGGATGCAGAAAAGCAGTATGAAA

10 110 120 130 140 150
| | | | |
AGGATCCTGATGACTTCAACAAGAGGGCACTGCATGATCGGGAGAGTGTCT

15 160 170 180 190 200
| | | | |
GCAGCTTCAATACAATCAAAAATTGATGAATTGAAGCGCCAACCTGCCGA

20 210 220 230 240 250
| | | | |
CAGGATTGCAGCAGGGAAGAATATTGGGCAAGACCGGGATCCTACAGGGG

25 260 270 280 290 300
| | | | |
TAGAGCCGGGTGATCATCTCAAAGAGAGATCAGCACTAAGCTATGGGAAT

30 310 320 330 340 350
| | | | |
AACTGGACCTGAATAGTCTTGACATTGATGAACCTACAGGACAGACAGC

35 360 370 380 390 400
| | | | |
TGATTGGTTGACCATAATTGTCTATCTGACTTCATTGTGGTCTGATCA

410 420 430 440 450
| | | | |
TCTTAAAGGCACCTGTACATGTTAAACAACAAGAGGCAGGAGACTTCAAAG

460 470 480 490 500
| | | | |
GACAACAAGGGATGAGGATCAGATTCAAGGATGACAGCTCATATGAGGA

510 520 530 540 550
TGTCAATGGAATCAGAAAACCCAAACATCTGTATGTGTCAATGCCAAACG

560 570 580 590 600
CCCAATCCAGCATGAAGGCTGAAGAGATAACACCTGGAAGATTCCGCACT

10 610 620 630 640 650
GCAGTATGTGGGCTATATCCTGCACAGATAAAGGCAAGGAACATGGTGAG

660 670 680 690 700
CCCTGTCATGAGTGTAGTTGGGTTTTTGGCACTGGCAAAAGATTGGACAT

710 720 730 740 750
CTAGAATTGAAGAATGGCTTGGTGACCCCTGCAAGTTTATATGGCGAATCT

20 760 770 780 790 800
CCAATTGCTGGGAGTTTATCTGGGAATCCCGTGAATCGTAACTATATCAG

810 820 830 840 850
ACAGAGACAAGGTGCACCTTGAGGGATGGAGCCAAAGGAATTTCAAGCCC

30 860 870 880 890 900
TCAGGCAACATGCAAAGGATGCTGGGTGTACACTGGTTGAGCATATTGAG

910 920 930 940 950
TCACCATCATCAATATGGGTGTTTGCTGGGGCCCCTGATAGGTGTCCACC

960 970 980 990 1000
AACATGTTTGTGTCGGAGGGATGGCTGAGTTAGGTGCCTTCTTTCTA

40

1010 1020 1030 1040 1050
TACTTCAGGATATGAGGAACACAATCATGGCTTCAAAAACTGTGGGCACA

1060 1070 1080 1090 1100
GCTGATGAAAAGCTTCGAAAGAAATCATTCATTCTATCAATCATACCTCAG

1110 1120 1130 1140 1150
ACGCACACAATCAATGGGAATACAACCTGGACCAGAGGATAATTGTTATGT

1160 1170 1180 1190 1200
TTATGTTGCCCTGGGAAAGGAGGCAGTGGACAACCTTCATCTCGGTGAT

1210 1220 1230 1240 1250
GACATGGACCCAGAGCTTCGTAGCCTGGCTCAGATCCTGATTGACCAGAA

1260 1270 1280 1290
AGTAAAAGAAATCTCGAACCAAGGAACCTTTGAAACTCTAA

30

Further, the present invention provides a recombinant expression plasmid including the nucleocapsid gene of Seoul virus R22 of the present invention.

5 Furthermore, the present invention provides a transformed *Escherichia coli* with the recombinant expression plasmid of the present invention.

10 Furthermore, the present invention provides a method for producing a fused form of nucleocapsid protein of Seoul virus R22 in high yield which comprises culturing the transformed *E. coli* of the present invention on an appropriate medium to express the said nucleocapsid protein, and isolating and purifying the expressed nucleocapsid protein from the cultures.

15 Furthermore, the present invention provides a highly purified fused form of nucleocapsid protein of Seoul virus R22 having the following amino acid sequence:

20

25

30

	10	20	30	40	50
	MASMTGGQ	QMG	RGS	MA	TME
	I	Q	R	E	I
	S	A	H	E	G
	L	V	I	A	R
	Q	K	V	K	D
	A	E	K	Q	Y
	E	K	D	P	
10	60	70	80	90	100
	DDFN	KRAL	HD	RES	VAA
	S	I	Q	S	K
	I	D	E	L	K
	R	Q	L	A	D
	R	I	A	A	G
	N	I	G	Q	D
	R	D	P	T	G
	V	E	P		
	110	120	130	140	150
	GDHL	KERS	AL	SY	GN
	T	L	D	N	S
	L	D	I	D	E
	P	T	G	Q	T
	A	D	W	L	T
	I	I	V	Y	L
	T	S	F	V	V
	L	I	I	L	K
20	160	170	180	190	200
	ALY	ML	T	T	R
	Q	T	S	K	D
	N	K	G	M	R
	I	R	F	K	D
	D	S	S	Y	E
	D	V	N	G	I
	R	K	P	K	I
	L	Y	S	M	P
	N	A	Q	S	
	210	220	230	240	250
	SMK	AEE	I	T	P
	G	R	F	R	T
	A	V	C	G	L
	P	A	Q	I	K
	A	R	N	M	V
	S	P	V	M	S
	V	G	F	L	A
	L	A	K	D	W
	T	S	R	I	
30	260	270	280	290	300
	EE	W	L	G	A
	P	C	K	F	M
	A	E	S	P	I
	A	G	S	L	S
	G	N	P	V	N
	R	N	Y	I	R
	Q	R	Q	G	A
	L	A	G	M	E
	P	K	E	F	Q
	A	L	R		
	310	320	330	340	350
	H	A	D	A	G
	C	T	L	V	E
	H	I	E	S	P
	S	S	I	W	V
	F	A	G	A	P
	D	R	C	P	T
	C	L	F	V	G
	G	M	A	E	L
	G	A	F	F	S
	I	L	Q		
40	360	370	380	390	400
	D	M	R	N	T
	I	M	A	S	K
	T	V	G	T	A
	D	E	K	L	R
	K	K	S	S	F
	Y	Q	S	Y	L
	R	R	T	Q	S
	M	G	I	Q	L
	D	Q	R	I	I
	V	M	F	M	V
	410	420	430	440	
	A	W	G	K	E
	A	V	D	N	F
	H	L	G	D	D
	P	E	L	R	S
	L	A	Q	I	L
	I	D	Q	K	V
	K	E	I	S	N
	Q	E	P	L	K

Furthermore, the present invention provides a pharmaceutical composition for diagnosis of HFRS comprising the nucleocapsid protein of the present invention in combination with a pharmaceutically acceptable carrier or excipient.

5

Furthermore, the present invention provides a use of the pharmaceutical composition comprising the nucleocapsid protein of the present invention in determination on the formation of the antibodies to hantaviruses in a subject administered with a vaccine for HFRS.

10

Furthermore, the present invention provides a diagnostic formulation for HFRS comprising the nucleocapsid protein of the present invention coated on a 96-well plate.

15

Furthermore, the present invention provides a diagnostic formulation for HFRS comprising the nucleocapsid protein of the present invention adsorbed on a nitrocellulose membrane.

20

Furthermore, the present invention provides a vaccine for prevention of HFRS comprising the nucleocapsid protein of the present invention as an active ingredient in combination with a pharmaceutically acceptable adjuvant. The adjuvant may be selected from a group consisting of aluminium hydroxide gel, chimerosal and tablet gelatin, and a mixture thereof.

25

BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 shows the sites of the chemically synthesized on the nucleocapsid gene of Seoul virus strain R22 nucleocapsid gene.

30

Fig. 2 is a schematic construction diagram showing a recombinant

expression plasmid pET-sNP containing Seoul virus R22 nucleocapsid gene.

Fig. 3 is a flow diagram showing a purification process for Seoul virus R22 nucleocapsid protein expressed by transformant *E. coli* BL containing plasmid pET-sNP.

Fig. 4 is (a) polyacrylamide gel electrophoresis and (b) western blots of Seoul virus R22 nucleocapsid protein expressed by transformant *E. coli* BL containing plasmid pET-sNP.

Fig. 5 is western blots of Seoul virus R22 nucleocapsid protein expressed by transformant *E. coli* BL containing plasmid pET-sNP using (a) human patient blood and (b) anti-nucleocapsid protein monoclonal antibodies.

Fig. 6 is a photograph showing the reaction of patient serum (P) or healthy subject serum (N) on nitrocellulose membrane adhered by various concentrations of Seoul virus R22 nucleocapsid protein.

Fig. 7 is western blots of nucleocapsid proteins expressed by several transformant *E. coli* strains containing different vectors.

DETAILED DESCRIPTION OF THE INVENTION

The present invention was accomplished through the amplification of the fully elucidated nucleotide sequence of a nucleocapsid gene of Seoul virus R22, the preparation of a recombinant expression plasmid, the production of a transformed *E. coli*, the cultivation of the transformant, the isolation and purification of the expressed nucleocapsid protein, and the evaluation of the diagnostic agent and vaccine comprising the nucleocapsid protein on efficacy and safety.

5 A large amount of the nucleocapsid gene of Seoul virus R22 to be cloned into an expression vector was prepared through twice polymerase chain reactions using three primers having the following nucleotide sequences, respectively:

NP 1 (17MER): 5'-TAGTAGTAGACTCCCTA-3'

NP 2 (23MER): 5'-CCAGATCTATGGCAACTATGGAG-3'

*Bgl*II

NP 3 (22MER): 5'-GGAATTCCTTAGAGTTTCAAAGG-3'

*Eco*R I

15

The first polymerase chain reaction used the designated NP1 and NP3 primers to amplify the nucleocapsid gene of Seoul virus R22. The second polymerase chain reaction used the designated NP2 and NP3 primers to introduce recognition sites for *Bgl*II and 20 *Eco*RI into the nucleocapsid gene, which will be thereby cloned into a commercially available expression vector pET-3a (Stratagene, cat#211621).

25 Since the vector pET-3a used for the cloning of the nucleocapsid gene of the present invention includes s10 sequence, the nucleocapsid protein is expressed as a form of a fused protein having additional 14 amino acids at the amino terminus.

30 Fig 2. illustrates a whole process for constructing a recombinant plasmid for expression of the nucleocapsid gene of the present invention by cloning the said gene into the vector pET-3a. The resulting recombinant

plasmid was designated as pET-sNP.

5 A novel transformed microorganism was produced by introducing the plasmid pET-sNP of the present invention into a host cell, *E. coli* BL21(DE3) (Stratagene, cat#211621) through electric shock and was proved as being capable of massively producing the desired nucleocapsid protein. This microorganism, referred to as *E. coli* BL(pET-sNP), was deposited with the Korean Culture Center of Microorganisms under the Budapest Treaty on the International Recognition of the Deposit of Microorganisms for the Purposes of
10 Patent Procedure on September 10, 1997 and the accession number was designated as KFCC-10111.

The nucleotide sequencing of the nucleocapsid gene of Seoul virus R22 was carried out by using Auto Reader Sequencing Kit (Pharmacia Co.,
15 cat#27-2690-20, cat#18-1033-13) in accordance with a known dideoxy method (PNAS 74, p5463, 1977). Then, the recombinant expression plasmid pET-sNP was used as a template and the synthetic fragments having the following nucleotide sequences were used as a primer:

P1: 5' GGCTAGCATGACTGGTGG-3'

P2: CTATCTGACTTCATTTGTGG

5 **P3:** ACCCAAACATCTGTATGTG

P4: GTTTATCTGGGAATCC

P5: GAGGAACACAATCATGG

10 **P6:** CCATTATTATCATAGC

P7: TGATTGIGTGCGTCTGAGGT

15 **P8:** ATTCTTCAATTCTAGATGTC

P9: CAGTGCCTTTAAGATGAT

20 In order to ensure the accuracy of the nucleotide sequencing, the nucleocapsid gene was twice analysed from 5'-end to 3'-end and, reversely, from 3'-end to 5'-end. The elucidated nucleotide sequence of the nucleocapsid gene of Seoul virus R22 in comparison with the known nucleotide sequence of the nucleocapsid gene of Seoul virus SR11(Virology 176, pp114-125, 1990)

25 is as follows:

	10	20	30	40	50	
	ATGGCAACTATGGA	CGAAATCCAGAGAGAAATCAGTGCTCACGAGGGGCA				R-22 .SEQ
	ATGGCAACTATGGA	CGAAATCCAGAGAGAAATCAGTGCTCACGAGGGGCA				SR-11 .SEQ
10	60	70	80	90	100	
	GCTTGTGATAGCACGCCAGAA	GTCAAGGATGCAGAAAAGCAGTATGAAA				R-22 .SEQ
	GCTTGTGATAGCACGCCAGAA	GTCAAGGATGCAGAAAAGCAGTATGAGA				SR-11 .SEQ
20	110	120	130	140	150	
	AGGATCCTGATGACTT	MAACAAGAGGGCACTGCATGATCGGGAGAGTGTC				R-22 .SEQ
	AGGATCCTGATGACTT	MAACAAGAGGGCACTGCATGATCGGGAGAGTGTC				SR-11 .SEQ
	160	170	180	190	200	
	GCAGCTTCAATACAATCAAAAATTGATGAATTGAAGCGCCAACCTGCCGA					R-22 .5SEQ
	GCAGCTTCAATACAATCAAAAATTGATGAATTGAAGCGCCAACCTGCCGA					SR-11 .SEQ
30	210	220	230	240	250	
	CAGGATTGCAGCAGGGAAGAAAT	TGGGCATGACCGGGATCCTACAGGGG				R-22 .SEQ
	CAGGATTGCAGCAGGGAAGAAAT	TGGGCATGACCGGGATCCTACAGGGG				SR-11 .SEQ
40	260	270	280	290	300	
	TAGAGCCGGTGATCATCT	TAAAGATGAGATCAGCACTAAGCTATGGGAAT				R-22 .SEQ
	TAGAGCCGGTGATCATCT	TAAAGATGAGATCAGCACTAAGCTATGGGAAT				SR-11 .SEQ
	310	320	330	340	350	
	ACACTGGACCTGAATAGTCTTGACATTGATGAACCTACAGGACAGACAGC					R-22 .SEQ
	ACACTGGACCTGAATAGTCTTGACATTGATGAACCTACAGGACAGACAGC					SR-11 .SEQ
50	360	370	380	390	400	
	TGATTGGGTGACCATAAATGTCTATCTGAC	TTCATTGTGGTCCATGATCA				R-22 .SEQ
	TGATTGGGTGACCATAAATGTCTATCTGAC	TTCATTGTGGTCCATGATCA				SR-11 .SEQ

	410	420	430	440	450	
	TCTT	MAAGGC	ACTGTACATGTTAA	CAACA	AGGAGGCAGACTTCAAAG	R-22 .SEQ
	TCTT	MAAGGC	ACTGTACATGTTAA	CAACA	AGGAGGCAGACTTCAAAG	SR-11 .SEQ
10	460	470	480	490	500	
	GACAACA	AMGGG	ATGAGGATCAGATTCA	AGGATGACAGCTCATATGAGGA		R-22 .SEQ
	GACAACA	AMGGG	ATGAGGATCAGATTCA	AGGATGACAGCTCATATGAGGA		SR-11 .SEQ
	510	520	530	540	550	
	TGTC	AATGGAATCAGAAA	CCCCAA	CATCTGTATGTGCAATGCCAAACG		R-22 .SEQ
20	TGTC	AATGGAATCAGAAA	CCCCAA	CATCTGTATGTGCAATGCCAAACG		SR-11 .SEQ
	560	570	580	590	600	
	CCCAATCCAGCATGAAGGCTGAAGAGATAACAC	CTGGAAGATTCCGCACT				R-22 .SEQ
	CCCAATCCAGCATGAAGGCTGAAGAGATAACAC	CTGGAAGATTCCGCACT				SR-11 .SEQ
30	610	620	630	640	650	
	GCAGTATGTGG	CTATATCCTGCACAGATAAAGGCAAGGAA	ATGGT	TAG		R-22 .SEQ
	GCAGTATGTGG	CTATATCCTGCACAGATAAAGGCAAGGAA	ATGGT	TAG		SR-11 .SEQ
	660	670	680	690	700	
	CCCTGTCATGAGTGTAGTTGGGTT	TTTGGCACTGGCAAAAGAT	TGGACAT			R-22 .SEQ
40	CCCTGTCATGAGTGTAGTTGGGTT	TTTGGCACTGGCAAAAGAT	TGGACAT			SR-11 .SEQ
	710	720	730	740	750	
	CTAGAATTGAAGAATGGCT	CGGTGCACCCCTGCAAATT	TATGGCGGA	TTCT		R-22 .SEQ
	CTAGAATTGAAGAATGGCT	CGGTGCACCCCTGCAAATT	TATGGCGGA	TTCT		SR-11 .SEQ
50	760	770	780	790	800	
	CCAATTGCTGGGAGTTTATCTGGGAATCC	GTGAATCGT	TA	CTATATCAG		R-22 .SEQ
	CCTATTGCTGGGAGTTTATCTGGGAATCC	GTGAATCGT	TA	CTATATCAG		SR-11 .SEQ

	810	820	830	840	850	
	ACAGAGACAAGGTGCACTTGCAGGGATGGAGCCAAAGGAATTTCAAGCCC					R-22 .SEQ
	ACAGAGACAAGGTGCACTTGCAGGGATGGAGCCAAAGGAATTTCAAGCCC					SR-11 .SEQ
10	860	870	880	890	900	
	TCAGGCAACATTCAAAGGATGCTGGTTGTACACTTGTGATCATATTGAG					R-22 .SEQ
	TCAGGCAACATTCAAAGGATGCTGGTTGTACACTTGTGATCATATTGAG					SR-11 .SEQ
	910	920	930	940	950	
	TCACCATCATCAATATGGGTGTTTGTCTGGGGCCCTGATAGGTGTCCACC					R-22 .SEQ
20	TCACCATCATCAATATGGGTGTTTGTCTGGGGCCCTGATAGGTGTCCACC					SR-11 .SEQ
	960	970	980	99	1000	
	AACATGTTTGTGTCGGAGGGATGGCTGATTTAGGTGCCTTCTTTTCTA					R-22 .SEQ
	AACATGTTTGTGTCGGAGGGATGGCTGATTTAGGTGCCTTCTTTTCTA					SR-11 .SEQ
30	1010	1020	1030	1040	1050	
	TACTTCAGGATATGAGGAACACAATCATGGCTTCAAAAAGTGTGGGCACA					R-22 .SEQ
	TACTTCAGGATATGAGGAACACAATCATGGCTTCAAAAAGTGTGGGCACA					SR-11 .SEQ
	1060	1070	1080	1090	1100	
	GCTGATGAAAAGCTTCGAAAGAAATCATCTATCAATCATACCTCAG					R-22 .SEQ
40	GCTGATGAAAAGCTTCGAAAGAAATCATCTATCAATCATACCTCAG					SR-11 .SEQ
	1110	1120	1130	1140	1150	
	ACGCACACAATCAATGGGAATACAACCTGGACCAGAGGATAATTGTTATGT					R-22 .SEQ
	ACGCACACAATCAATGGGAATACAACCTGGACCAGAGGATAATTGTTATGT					SR-11 .SEQ
50	1160	1170	1180	1190	1200	
	TTATGGTTGCTGGGGAAAGGAGGCAGTGGACAACCTTCATCTCGGTGAT					R-22 .SEQ
	TTATGGTTGCTGGGGAAAGGAGGCAGTGGACAACCTTCATCTCGGTGAT					SR-11 .SEQ

	1210	1220	1230	1240	1250	
	GACATGGA	CCAGAGCTTCGTAGCCTGGCTCAGATC	TTGATTGACCAGAA			R-22 .SEQ
	GACATGGA	CCAGAGCTTCGTAGCCTGGCTCAGATC	TTGATTGACCAGAA			SR-11 .SEQ
10	1260	1270	1280	1290		
	AGTMAA	MGAAATCTCAACCAGGAACCTTTGAAA	TTTAA			R-22 .SEQ
	AGTMAA	MGAAATCTCAACCAGGAACCTTTGAAA	TTTAA			SR-11 .SEQ

15 in which the reversed A, T, G, and C indicate the different nucleotides between nucleotide sequences of nucleocapsid genes of Seoul virus R22 and Seoul virus SR11. A comparison of the two nucleotide sequences reveals that 1241 nucleotides are same and thus the identity is calculated as 96.2%. In addition, upon comparison of the two presumed amino acid sequences from

20 the Seoul virus R22 and R11 nucleotide sequences as illustrated below, it reveals that 423 amino acids are same and thus the identity is calculated as 98.6%:

	10	20	30	40	50	
	MATMEEIQREISAHEGQLVIARQKVKDAEKQYEKDPDD	ENKRALHDRESV				R-22 .PRO
	MATMEEIQREISAHEGQLVIARQKVKDAEKQYEKDPDD	ENKRALHDRESV				SR-11 .PRO
30	60	70	80	90	100	
	AASIQSKIDELKRQLADRIAAGKNIGQDRDPTGVEPGDHLKERSALSYGN					R-22 .PRO
	AASIQSKIDELKRQLADRIAAGKNIGQDRDPTGVEPGDHLKERSALSYGN					SR-11 .PRO
40	110	120	130	140	150	
	TLDLNSLIDIEPTGQTADWLTIIIVYLTSEFVV	IIILKALYMLTTRGRQTSK				R-22 .PRO
	TLDLNSLIDIEPTGQTADWLTIIIVYLTSEFVV	IIILKALYMLTTRGRQTSK				SR-11 .PRO

	160	170	180	190	200	
	DNKGMRIRFKDDSSYEDVNGIRKPKHLVVSMPNAQSSMKAEIITPGRFRT					R-22 .PRO
	DNKGMRIRFKDDSSYEDVNGIRKPKHLVVSMPNAQSSMKAEIITPGRFRT					SR-11 .PRO
	210	220	230	240	250	
10	AVCGLYPAQIKARNMVSPVMSVVGFLALAKDWTSRIEEWLGAPCKFMAES					R-22 .PRO
	AVCGLYPAQIKARNMVSPVMSVVGFLALAKDWTSRIEEWLGAPCKFMAES					SR-11 .PRO
	260	270	280	290	300	
	IIAGSLSGNPVNRNYIRQRQGALAGMEPKFQALRQHAKDAGCTLVEHIE					R-22 .PRO
20	IIAGSLSGNPVNRNYIRQRQGALAGMEPKFQALRQHAKDAGCTLVEHIE					SR-11 .PRO
	310	320	330	340	350	
	SPSSIWVFAGAPDRCPPTCLFVGGMAELGAFFSILQDMRNTIMASKTVGT					R-22 .PRO
	SPSSIWVFAGAPDRCPPTCLFVGGMAELGAFFSILQDMRNTIMASKTVGT					SR-11 .PRO
	360	370	380	390	400	
30	ADEKLRKKSSFYQSYLRRTQSMGIQLDQRIIVMFMVAWGKEAVDNPHLGD					R-22 .PRO
	ADEKLRKKSSFYQSYLRRTQSMGIQLDQRIIVMFMVAWGKEAVDNPHLGD					SR-11 .PRO
	410	420	430			
	DMDPELRSLAQILIDQKVKEISNQEPFKL					R-22 .PRO
40	DMDPELRSLAQILIDQKVKEISNQEPFKL					SR-11 .PRO

in which the reversed characters indicate the different amino acids between amino acid sequences of nucleocapsid proteins from Seoul virus R22 and SR11.

The fragments which serve as a primer for sequencing the nucleocapsid gene of Seoul virus R22 were chemically synthesized on the basis of the known nucleotide sequence of the nucleocapsid gene of Seoul virus SR-11. Fig. 1 shows the location of the chemically synthesized primers on the nucleocapsid gene of Seoul virus R22.

The culture of the transformed *E. coli* of the present invention can be performed according to methods conventionally known in the art of a genetic engineering technology. The high purification of the expressed nucleocapsid protein was accomplished through ammonium sulfate precipitation, gel filtration and phenyl sepharose column chromatography. As illustrated in Fig. 3, subsequent polyacrylamide gel electrophoresis and western blotting were carried out to affirm the purified nucleocapsid protein. The results of polyacrylamide gel electrophoresis and western blotting shown in Figs. 4 and 5, respectively, prove that the purified substance corresponds to the nucleocapsid protein. In addition, the purity of the nucleocapsid protein was evaluated as at least 90% from the result of polyacrylamide gel electrophoresis.

The purified nucleocapsid protein of the present invention includes additional 14 amino acids (Met-Ala-Ser-Met-Thr-Gly-Gly-Gln-Gln-Met-Gly-Arg-Gly-Ser) at the N-terminus as compared to the corresponding naturally occurred nucleocapsid protein. The additional amino acid sequence is derived from s10 leader sequence located at the front of *Bam*HI site, cloning site of plasmid pET-3a. The molecular weight of the present nucleocapsid protein was measured as approximately 50 kDa.

An alternative recombinant plasmid, designated as pKK-sNP, for expression of the nucleocapsid protein gene of Seoul virus R22 was constructed by the inventors. The construction of the plasmid pKK-sNP is for the purpose of inspecting the influence of a cloning vector on the expression

of the nucleocapsid protein gene of Seoul virus R22. The procedure for constructing the plasmid pKK-sNP was similar to that of the plasmid pET-sNP except that pKK223-3 having the strong *tac* promoter (Pharmacia Biotech, cat#27-4935-01) was used as a cloning vector instead of pET-3a. It was found that the pET-3a express the nucleocapsid protein of Seoul virus R22 much higher than the pKK223-3. It is comprehended that such result is because the fused form of the nucleocapsid protein with additional 14 amino acids at the N-terminus allows the expressed nucleocapsid protein to be more stable in *E. coli* or because s10 leader sequence existing in pET-3 plays a role in increasing either the transcription efficiency of the cloned nucleocapsid protein gene or the translation efficiency in the protein synthesis from the transcript mRNA.

For the evaluation of the nucleocapsid protein expression capability of the plasmid pET-sNP of the present invention, another plasmid, designated as pET-NP was constructed by cloning the nucleocapsid gene of prototype Hantaan virus 76-118 (Virology 155, pp633-643, 1986) into pET-3a in accordance with the same procedure as used in the construction of pET-sNP of the present invention. The two expressed nucleocapsid proteins of Seoul virus R22 and Hantaan virus 76-118 were separately detected by western blotting using monoclonal antibodies to the Hantaan virus nucleocapsid protein. The results are shown in Fig. 7. It can be seen that the expressed Seoul virus R22 nucleocapsid protein is twice as high as the expressed Hantaan virus 76-118 nucleocapsid protein. The results are likely attributed to the higher stability of the Seoul virus R22 nucleocapsid protein than that of the Hantaan virus 76-118 nucleocapsid protein.

An assay on a diagnostic efficacy of the Seoul virus R22 nucleocapsid protein of the present invention was performed according to conventional methods. The nucleocapsid protein coated on 96-well plate or nitrocellulose

5 membrane was reacted with patient serum or vaccinee serum. In order to ensure the accuracy of the assay, the blood collected from the patient was re-assayed by an indirect immunofluorescence antibody assay. The results are shown in Fig. 6. It can be seen that the patient serum was accurately detected by both of the Seoul virus R22 nucleocapsid proteins coated on 96-well plate or nitrocellulose membrane. Also it was appreciated that the Seoul virus R22 nucleocapsid protein can be used to examine the formation of the antibodies in vaccinated subjects with HFRS vaccines.

10 The purified nucleocapsid protein of Seoul virus R22 of the present invention is mixed with conventional adjuvants, especially aluminium hydroxide gel, prior to its use as a formulated vaccine for HFRS. The preferred amount of the aluminium hydroxide gel used is less than 0.625 mg/ 0.5 ml of vaccine solution. In addition to the adjuvant, chimerosal and purified gelatin may be
15 used as a preservative in amount of 0.01% (w/v) and a stabilizing agent in amount of 0.02% (w/v), respectively. Also, 0.01% (w/v) of Tween 80 can be added.

20 The invention will now be explained in details with reference to the following illustrative Examples.

Example 1

Isolation of genomic RNA from Seoul virus R22 and synthesis of cDNA

25 100 μ l of culture solution of Seoul R22 virus was mixed with 400 μ l of Solution A (4.2 M guanidine isothiocyanate, 25 ml Tris-HCl, pH 8.0, 0.5% Sarkosyl, 0.7% β -mercapto ethanol) and then with 50 μ l of Solution B (1 M Tris-HCl, pH 8.0, 0.1 M EDTA, 10% SDS). After incubation of the resuting solution at 65°C for 5 minutes, it was mixed with an equal volume of a
30 mixed solution of phenol and chloroform (1:1). After another incubation at 6

5°C for further 30 minutes, the mixture was centrifuged. The supernatant was taken, and the remaining solution was mixed with further 300 µl of Solution A, then incubated at 65°C for 5 minutes. Following centrifugation of the solution, the supernatant was taken and combined with the first supernatant.

5 The total supernatant was extracted with a mixed solution of phenol and chloroform (1:1) and then with chloroform. The extracted solution was mixed with 1/10 volume of 3 M sodium acetate and two volumes of isopropyl alcohol and the resulting mixture was kept at -20°C for 16 hours. The solution was then centrifuged at 12,000 rpm for 15 minutes, and the precipitate was

10 washed with 70% ethyl alcohol twice and dried. The dried precipitate was dissolved in 10 µl of sterilized distilled deionized water which does not contain ribonuclease at all and the resulting solution was kept at 4°C. 5 µl of the purified genomic RNA was used to synthesize cDNA. The synthetic reaction was carried out at 37°C for 1 hour under the conditions indicated in

15 Table 1 below.

Table 1

Tris-HCl, pH 8.4	10 mM
KCl	50 mM
MgCl ₂	7 mM
4 dNTPs	1 mM
RNase inhibitor	1 U/µl
Random primer	50 pmol
AMV reverse transcriptase	12 Units

25

Example 2**Amplification of nucleocapsid gene by the polymerase chain reaction**

The nucleocapsid gene to be cloned into a known plasmid pET-3a was

30 amplified by the polymerase chain reaction (PCR) with the primers illustrated above. The DNA Thermal Cycler 480 (Perkin Elmer) was used for the

PCR. The reaction conditions and procedures are described in Table 2 below.

Table 2

Composition for PCR	Tris-HCl, pH 8.4	10 mM
	KCl	50 mM
	MgCl ₂	2.5 mM
	4 dNTPs	0.2 mM
	Primers	50 pmol
	Taq polymerase	2.5 Units
Procedures for PCR	92°C (15 sec)→46°C (2 min)→72°C (3 min)	20 cycles
	92°C (15 sec)→46°C (2 min)→72°C (3.5 min)	15 cycles
	92°C (15 sec)→46°C (2 min)→72°C (10 min)	1 cycle

5 µl of cDNA solution prepared by Example 1 was first amplified by the polymerase chain reaction with NP1 and NP3 primers. 5 µl of the first reacted cDNA solution was continuously subject to the second polymerase chain reaction using NP2 and NP3 primers which contain recognition sites of *Bgl*II (AGATCT) and *Eco*RI (GAATTC) at 5' ends, respectively.

Example 3

Construction of expression plasmid pET-sNP

The process for the cloning of the nucleocapsid gene was depicted in Fig. 2. The two double-stranded DNA fragments amplified in Example 2 were characterized by agarose gel electrophoresis and then the DNA fragment containing 1.3 kb of nucleocapsid protein was recovered using GENECLEAN kit. The recovered DNA fragments were digested with restriction enzymes *Bgl*II and *Eco*RI, extracted once with a mixed solution of phenol and chloroform (1:1) and dissolved in 20 µl of sterile distilled water. Likewise, 5 µg of plasmid pET-3a as a cloning vector was digested with *Bgl*II and *Eco*RI, heated to 70°C for 10 minutes in presence of 5 mM of EDTA, extracted once with a mixed solution of phenol and chloroform (1:1) and dissolved in 20 µl

of sterile distilled water. 5 µl of the vector was mixed with 10 µl of the restriction enzyme-cleaved nucleocapsid DNA and the ligation reaction was carried out at 25°C for 3 hours in presence of T4 DNA ligase to form the desired expression plasmid pET-sNP.

5

Example 4

Construction of plasmid pKK-sNP

As primers, random 6-mers were used to synthesize cDNA from genomic RNA of Seoul virus R22. The first amplification of DNA was carried out by using the cDNA as template with NP1 and NP3 primers illustrated above. The second amplification of the DNA fragment was carried out by using the first amplified fragment as template with the following NP4 and NP5 primers which contain recognition sites of restriction enzymes *EcoRI* (GAATTC) and *SalI* (GTCGAC) for cloning into pKK223-3, respectively:

10

15

NP 4 (23MER): 5'-CCGAAATTCATGGCAACTATGGAG-3'

EcoRI

NP 5 (23MER): 5'-GCGTCGACTTAGAGTTTCAAAGG-3'

SalI

25

30

The amplified nucleocapsid DNA fragment recovered from agarose gel was treated with Klenow enzyme to make both ends blunt and then the resulting blunt-ended DNA was treated with *EcoRI* to make one end cohesive. The vector pKK223-3 was digested with *EcoRI* and *SmaI* and ligated with the *EcoRI*-cleaved nucleocapsid gene. The resulting recombinant plasmid pKK-sNP

was introduced into *E. coli* JM105. It was found that pKK223-3 contains two *Sma*I sites. This is why *Sma*I site was used instead of *Sac*I for the construction of pKK-sNP.

5 **Example 5**

Production of transformed *E. coli*

An electric shock was used for the transformation and *E. coli* BL21(DE3) was used as a host cell for pET-sNP. 20 ml of LB medium was
10 inoculated with a plate culture of the microorganism *E. coli* BL21(DE3) and a shake culture was carried out at 37°C for 18 hours. 1 L of freshly made LB medium was inoculated with the first shake culture and a second shake culture was carried out at 37°C until the optical density of 0.5-0.8 at 600 nm was reached. The resulting culture solution stood at 0°C for 20 minutes and
15 centrifuged to recover the cells. The recovered cell pellet was successively washed once with 1 L of cold sterile distilled water, once with 0.5 L of cold sterile distilled water and once with 20% glycerol. The cells were resuspended in 3 ml of 10% glycerol, divided into aliquots and kept at -70°C. Gene-Pulser (Bio-Rad) was used in electrical shock. A mixture of 40 µl
20 aliquots of cells with 2 µl of DNAs was placed into cuvette with 0.2 cm of electrode gap. After one electric shock was pulsed on the cuvette following the adjustment of the Gene-Pulser at 25 µF of capacitance, 200 Ω of electric resistance and 12.5 kV/cm of electric field strength, immediately 1 ml of SOC medium (2% bactotrypton, 0.5% yeast extract, 10 ml NaCl, 2.5 mM KCl, 10
25 mM MgCl₂, 10 mM MgSO₄, 20 mM glucose) was added. After a shake culture at 37°C for 1 hour, 0.1 ml and 0.9ml of cell cultures were sprayed on two LB medium agar plate with 50 µg/ml of ampicillin, respectively, and cultured in an incubator at 37°C for 12 to 18 hours. A loop of cells picked from the agar plate medium was put into 80 µl of cracking buffer (0.05 M
30 Tris, pH 6.8, 1% SDS, 2 mM EDTA, 0.4 M sucrose, 0.01% bromophenol

blue) and was made disperse by a vortex mixer. The disperse solution was centrifuged at 12,000 rpm for 15 minutes. The supernatant was subjected to an agarose gel electrophoresis to screen pET-sNP. The pET-sNP was reconfirmed by a digestion with restriction enzymes.

5

Example 6

Culture of transformant

The transformed cells were cultured overnight on LB medium (0.5% yeast extract, 1% bactotrypton, 1% NaCl, pH 7.0) with supplementary 0.5% glucose and 100 µg/ml of ampicilin. 1 L of the freshly made LB medium was inoculated with 5% overnight cell culture and was shaken at 37°C with the velocity of 200 rpm. Once the optical density of 0.5 to 0.8 at A₆₀₀ was reached, 0.1 to 2 mM IPTG was added to the culture solution and cultured for further 4 to 8 hours. The cells were recovered from the culture solution by centrifugation and washed once with 0.8% NaCl.

15

Example 7

Isolation and purification of nucleocapsid protein

20

A method for purifying the expressed nucleocapsid protein from a transformed E. coli with pET-sNP was illustrated in Fig. 3. The recovered cells were suspended in 50 to 100 ml of TE buffer solution (50 mM Tris, 1 mM EDTA, pH 8.0) and crushed by a sonicator. The sonication was continued until the concentration of the proteins in the crushed solution was no longer increased by a Bradford assay. The crushed solution was centrifuged at 8,000 x g for 1 hour. The amount of ammonium sulfate to be 25% to 50% of the saturated concentration was dissolved in the recovered supernatant. The resulting solution stood at room temperature for 1 hour and centrifuged at 8,000 x g for 30 minutes. The supernatant was discarded and the precipitate

25

30

was resuspended in 20 ml of TE buffer solution. The suspension was dialyzed twice in 2 L of TE buffer solution each for two hours to remove ammonium sulfate. The dialyzed solution was applied to gel filtration with Sepharacryl S200 (Pharmacia, Co), and then hydrophobic interaction chromatography with phenyl sepharose CL-4B resin (Pharmacia, Co). For loading of the samples, a solution of 40 mM $\text{KH}_2\text{PO}_4/\text{Na}_2\text{HPO}_4$ (pH 8.0) containing 0.6 M of ammonium sulfate was used, while, upon elution, a solution of 40 mM $\text{KH}_2\text{PO}_4/\text{Na}_2\text{HPO}_4$ (pH 8.0) without ammonium sulfate was used. Thereby, most nucleocapsid proteins were flown through, with most other proteins originated from *E. coli* being eliminated. The eluted nucleocapsid proteins were further dialyzed in PBS buffer solution and concentrated by Centricon or Centriprep (Amicon, Co.). All of the step-wise purified proteins were analyzed by polyacrylamide gel electrophoresis and western blotting (Fig. 4). The purity of final protein assumed to be higher than 90%.

Example 8

Western blotting of nucleocapsid protein

The purified proteins expressed from the transformed cells of the present invention were subjected to a polyacrylamide gel electrophoresis. The proteins on polyacrylamide gel were then transferred to nitrocellulose membranes and western blotting was carried out by using HFRS patient sera and anti-nucleocapsid protein monoclonal antibody ht9040. The membranes were reacted with 5% PBS solution (8 g of NaCl, 0.2 g of KCl, 1.44 g of Na_2HPO_4 , 0.24 g KH_2PO_4 , pH 7.4, per 1 L of PBS solution) containing skim milk for 30 minutes to permit only proteins having specificities to be adhered and then reacted with the above monoclonal antibody ht9040 at room temperature for more than one hour. The membranes were washed three or four times with PBST solution (PBS + 0.5% Tween 20) each for 5 to 10 minutes to remove the unadhered antibodies. The washed membranes were

immersed into PBS solution containing 5% skim milk and appropriately diluted peroxidase-labelled anti-mouse immunoglobulin G and shaken for 1 hour. The membranes were washed further three or four times with PBST solution each for 5 to 10 minutes and stained with 4-chloro-1-naphtol. The desired nucleocapsid protein specific band (about 50 Kd) was exhibited on the expected spots (Fig. 5).

Example 9

Diagnostic assay on the purified nucleocapsid protein coated on 96-well plate by ELISA

An enzyme-linked immunoadsorbent assay (ELISA) was carried out to determine whether the Seoul virus nucleocapsid protein expressed by the transformed E. coli of the present invention is capable of recognizing HFRS patient sera. Twenty (20) HFRS patient sera and four (4) normal sera as control were tested. Each microtitre well in EIA/RIA 96-well plate was coated with 100 µl of solution of the nucleocapsid protein (100 ng/well) in coating buffer (50 mM NaHCO₃, pH 9.0) at normal temperature for 1-2 hours and washed twice with PBS buffer. 100 µl of patient or normal sera diluted with PBS was placed into each microtitre well and reacted for 1 hour. The plate was washed twice with PBST buffer and reacted with 1/1000 diluted peroxidase-labelled anti-mouse immunoglobulin G for 1 hour. Subsequently, the plate was washed twice with PBST buffer and 100 µl of 0.1 M citrate-phosphate buffer (pH 4.9) containing 1 mg/ml of OPD (o-phenyldiamine dihydrochloride) and 0.03% H₂O₂ was placed into each microtitre well. After the plate was kept at room temperature for 20 to 30 minutes in the dark, the reaction was stopped by placing 50 µl of 1 M sulfuric acid into each microtitre well and the absorbance at 490 nm was measured by ELISA Reader. The ELISA titres were defined as the reciprocal of the maximum dilutions of sera that generated absorbance readings higher

than 0.2. The results were shown in Table 3 below. It should be noted from Table 3 that there are remarkable differences between ELISA titres of IgGs or IgMs from HFRS patients and those from normal humans with the expressed nucleocapsid protein. This indicates that ELISA using the expressed nucleocapsid protein of the present invention is very useful in the accurate diagnosis of HFRS. In order to enhance the accuracy of ELISA, all sera were subjected to indirect immunofluorescence assay. From Table 3, it should be noted that the results obtained by ELISA are completely consistent with those obtained by indirect immunofluorescence antibody assay.

10

Table 3

ELISA reactivities of HFRS patient sera and negative control human sera with the expressed nucleocapsid protein

Sample No.	Serum	ELISA(IgG)	ELISA(IgM)	IgG/IgM	*Indirect Immunofluorescence
1	Patient	8,000	1,000	8	+
2	Patient	8,000	<500	>16	+
3	Patient	8,000	2,000	4	+
4	Patient	64,000	1,000	64	+
5	Patient	8,000	500	16	+
6	Patient	1,000	4,000	0.25	+
7	Patient	1,000	<500	>2	+
8	Patient	1,000	<500	>2	+
9	Patient	4,000	2,000	2	+
10	Patient	8,000	1,000	8	+
11	Patient	1,000	<500	>2	+
12	Patient	2,000	500	>4	+
13	Patient	4,000	500	8	+
14	Patient	32,000	1,000	32	+
15	Patient	64,000	4,000	14	+
16	Patient	8,000	500	>16	+
17	Patient	500	1,000	0.5	+
18	Patient	8,000	4,000	2	+
19	Patient	1,000	<500	>2	+
20	Patient	16,000	8,000	2	+
21	Normal	100	50	2	-
22	Normal	100	50	2	-
23	Normal	400	50	8	-
24	Normal	100	50	2	-

* "+" and "-" signs represent test results positive and negative, respectively.

Example 10

Diagnostic assay by the use of the purified nucleocapsid protein-adhered nitrocellulose membrane

25

ELISA employing 96-well plate is useful in diagnosing many patients but requires the instrument ELISA reader. There is a need to conveniently diagnose a few HFRS patients occurred at rural or small areas.

30

The purified nucleocapsid proteins were diluted in PBS to make the

concentrations of 100, 50, 25, 13 and 6 µg/ml. The nitrocellulose membranes were immersed into the diluted solutions and the reactions were allowed by gently shaking it for 1 hour. The membranes were blocked by using PBS buffer solution with skim milk dissolved as 5%, dried at 30°C for 4 hours and reacted with 1/500 dilution of patient sera in PBS buffer at normal temperature for 1 hour. Then, the membranes were washed twice with PBST solution (PBS, 0.5% Tween 20) and were reacted with 1/1000 dilution of second peroxidase-labelled anti-human antibodies in PBS for 1 hour. Subsequently, the membranes were washed twice with PBST solution and were stained with coloring agent [25 ml of 0.1 M Tris, pH 7.4, 25 mg of 4-chloro-1-naphtol (5 mg/ml in methanol), 3 µl of H₂O₂, 20 ml of distilled water]. When the color was appeared on the membranes, the reaction was allowed to be stopped and the membranes were washed with distilled water. It was observed that 13 µg/ml to 100 µg/ml of nucleocapsid protein solution resulted in the conspicuous appearance of the color by response with patient sera, while even 100 µg/ml of nucleocapsid protein solution did not result in the appearance of the color by respond with any normal human sera.

Table 4 below shows the serological reactivities of 100 µg/ml or 10 µg/ml of nucleocapsid protein solution adhered on nitrocellulose membranes with twenty patient sera and four normal human sera. All sera were affirmed by performing indirect immunofluorescence antibody assay.

Table 4

Sample Nos.	Serum	*Nucleocapsid protein		**Indirect immunofluorescence
		100 µg/ml	10 µg/ml	
1	Patient	++	+	+
2	Patient	++	++	+
3	Patient	++	++	+
4	Patient	+++	++	+
5	Patient	++	+	+
6	Patient	+	+	+
7	Patient	+	+	+
8	Patient	+	+	+
9	Patient	++	++	+
10	Patient	++	++	+
11	Patient	+	+	+
12	Patient	++	+	+
13	Patient	++	+	+
14	Patient	+++	++	+
15	Patient	+++	++	+
16	Patient	++	+	+
17	Patient	+	+	+
18	Patient	++	++	+
19	Patient	+	+	+
20	Patient	++	++	+
21	Normal	-	-	-
22	Normal	-	-	-
23	Normal	-	-	-
24	Normal	-	-	-

* Number of "+" signs represents the thickness of colors.

** "+" and "-" signs represent test results positive and negative, respectively.

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Example 11

Assay on the reactivity of the purified nucleocapsid protein with HFRS vaccinee serum

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Ten individuals were vaccinated with current commercially available

vaccine, Hantavax(Korean Green Cross, Co.) according to the vaccination schedule recommended by the producer, and were bled one month from the last vaccination. The reactivities of the purified nucleocapsid protein of Seoul virus R22 with pre-inoculation sera or post-inoculation sera were observed by performing similar procedures to Examples 8 and 9 except for using vaccinee sera instead of patient sera. The concentration of the nucleocapsid protein adhered on nitrocellulose membrane was 10 µg/ml. The results are shown in Table 5 below. It is noted from Table 5 that the results obtained by the use of nitrocellulose membrane are completely consistent with ELISA results. The results in Table 5 indicate that the purified nucleocapsid protein of the present invention is very useful in determining whether HFRS vaccine induced antibodies following its vaccinations.

Table 5

Vaccinees	ELISA		*Nitrocellulose Membrane	
	Pre-vaccination	Post-vaccination	Pre-vaccination	Post-vaccination
1	100	4,000	-	+
2	100	16,000	-	++
3	100	8,000	-	++
4	200	16,000	-	++
5	100	32,000	-	++
6	100	8,000	-	++
7	100	16,000	-	++
8	100	8,000	-	++
9	100	4,000	-	+
10	200	1,000>	-	-

* Number of "+" signs represents the thickness of colors, and "+" and "-" signs represent test results positive and negative, respectively.

Example 12

Assay on the efficacy of the vaccine prepared from the purified nucleocapsid protein

0.5 ml of the purified nucleocapsid protein in Example 7 was mixed with 0.625 mg of aluminum hydroxide gel as adjuvant and the mixture stood at 4°C for 15 days. Thereafter, 0.01% (w/v) chimerosal and 0.02% gelatin were added to the mixture to prepare the final test vaccine.

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Guinea pigs were used for the assay of the induction of neutralization antibodies of the vaccine. The current commercially available vaccine prepared by inactivating the virus cultured on rat brain was used as control. The concentrations of the antigen to be inoculated on the experimental animals were 10 µg/0.5 ml, 20 µg/0.5 ml and 40 µg/0.5 ml. The sera of guinea pigs inoculated with test vaccine and control vaccine were subjected to plaque reduction neutralization test to assay the immune efficacy of the vaccines. The plaque reduction neutralization test was performed as follows:

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1) In order to obtain antibodies for the plaque reduction neutralization test, guinea pigs were subcutaneously inoculated three times at an interval of 10 days with three different concentrations of test vaccines and control vaccines (0.5 ml/inoculation).

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2) Sera from guinea pigs were inactivated at 56°C for 30 minutes and were diluted 1:10, 1:20, 1:40 and 1:80 in medium (MEM + M199 = 1:1) containing 3% fetal bovine serum.

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3) The diluted sera were mixed with equal volumes of Hantaan virus 76-118 diluted to be 70 PFU/culture vessel (diameter of 6 cm) in test tubes and reacted at 37°C for 1 hour.

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4) The preparative monolayer of Vero E6 cell in 6 cm culture vessel was inoculated with 0.2 ml of the above mixed solution and the reaction was allowed at 37°C for 90 minutes.

5) Inoculated medium was removed and 5 ml of the first agarose overlay was formed on each culture vessel. The composition of the first agarose overlay is as follows:

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M199 medium	50 ml
Fetal bovine serum	10 ml
7% NaHCO ₃	3 ml
Agarose	0.8 g
10 Distilled water	50 ml

The M199 medium contains no phenol red and the fetal bovine serum was heated to 56°C for 30 minutes.

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6) After the first agarose overlay was completed, inoculated cells were cultured at 37°C for 10 to 11 days.

7) 3 to 3.5 ml of the second agarose overlay was formed on each culture vessel. The composition of the second agarose overlay is as follows:

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M199	50 ml
400 mM MES*	10 ml
5% BSA	5 ml
0.6% Neutral Red	1 ml
25 1N NaOH	1.5 ml
Agarose	0.7 g
Distilled Water	32.5 ml

*(2-(N-Morpholino)ethane sulfonic acid, monohydrate)

30

8) After the second agarose overlay was completed, it was cultured for 3 days and the number of plaques with diameter of about 2 mm was counted.

Table 6

Serum	Serum Dilutions	Number of Plaques(PFU)
Normal	1:10	72
	1:20	74
	1:40	69
	1:80	74
Test Vaccine	1:10	8(40 μ g), 12(20 μ g), 19(10 μ g)
	1:20	14(40 μ g), 22(20 μ g), 31(10 μ g)
	1:40	16(40 μ g), 32(20 μ g), 42(10 μ g)
	1:80	25(40 μ g), 38(20 μ g), 64(10 μ g)
Control Vaccine	1:10	23
	1:20	31
	1:40	41
	1:80	63

It should be noted from Table 6 above that the induction of neutralization antibodies of the test vaccine prepared from the purified nucleocapsid protein at concentration of 40 μ g/0.5 ml and 20 μ g/0.5 ml are much higher than the control vaccine, while the inductions of neutralization antibodies of the test and control vaccines at concentration of 10 μ g/0.5 ml are equal. The results indicate that the vaccine prepared from the nucleocapsid protein of Seoul virus R22 according to the present invention exhibits excellent immunogenicity against HFRS as compared with the current available vaccines. Especially, since the vaccine of the present invention is prepared from the single nucleocapsid protein, rather than the virus *per se* which is believed to include toxic materials, it is apparent that the vaccine of the present invention is very superior to the current available vaccines in terms of safety.

WHAT IS CLAIMED IS:

1. A Seoul virus R22 nucleocapsid gene having the following nucleotide sequence:

```

5           10           20           30           40           50
   ATG GCA ACT ATG GAG GAA ATC CAG AGA GAA TCAG TGC TAC GAG GGC A

10           60           70           80           90          100
   GCT TGT GAT AGC ACG CCAG AAA GTCA AGG ATGC AGA AAG CAG TAT GAA A

15           110          120          130          140          150
   AGG ATC CTG ATG ACT TCA ACA AGAG GGC ACTGC ATG ATCG GAG AGT GTC

20           160          170          180          190          200
   GCAG CTTC AAT ACA ATCA AAAA ATTG ATGA ATTGA AGCG CCA ACTT GCC GA

25           210          220          230          240          250
   CAG GATTG CAG CAG GGA AGA ATATT TGGG CAAG ACCGGG ATC CTAC AGGGG

30           260          270          280          290          300
   TAG AGCCGG GTG ATCAT CTCAA AGAG AGATC AGCTA AGCTAT GGG AAT

35           310          320          330          340          350
   AACTGG ACCTGA ATAGT CTTG ACATTG ATGA ACCTAC AGGAC AGACAG C

40           360          370          380          390          400
   TGATTGG TTG ACCATA ATTGT CTATCTG ACTTC ATTTGTGG TCCTG ATCA

45           410          420          430          440          450
   TCTTAAAGGC ACTGTAC ATGTTA ACAACA AGAGG CAGG CAGACTTCAA AG

50           460          470          480          490          500
   GACAACA AAGG GATGAGG ATCAG ATTCA AGGATG ACAGCTCATATGAGGA

```

510 520 530 540 550
TGTCATGGAAATCAGAAAACCCAAACATCTGTATGTGTCAATGCCAAAG

560 570 580 590 600
CCCAATCCAGCATGAAGGCTGAAGAGATAACACCTGGAAGATTCCGCACT

10 610 620 630 640 650
GCAGTATGTGGGCTATATCCTGCACAGATAAAGGCAAGGAACATGGTGAG

660 670 680 690 700
CCCTGTCATGAGTGTAGTTGGGTTTTTGGCACTGCAAAAGATTGGACAT

20 710 720 730 740 750
CTAGAATTGAAGAATGGCTTGGTGCACCTGCAAGTTTATGGCGGAATCT

760 770 780 790 800
CCAATTGCTGGGAGTTTATCTGGGAATCCCGTGAATCGTAACATATATCAG

30 810 820 830 840 850
ACAGAGACAAGGTGCACCTTGCAAGGATGGAGCCAAAGGAATTTCAAGCCC

860 870 880 890 900
TCAGGCAACATGCAAAGGATGCTGGGTGTACACTGGTTGAGCATATTGAG

40 910 920 930 940 950
TCACCATCATCAATATGGGTGTTTGTGGGGCCCTGATAGGTGTCCACC

960 970 980 990 1000
AACATGTTGTGTTGTCGAGGGGATGGCTGAGTTAGGTGCTTCTTTTCTA

50 1010 1020 1030 1040 1050
TACTTCAGGATATGAGGAACACAATCATGGCTTCAAAAACGTGGGCACA

1060 1070 1080 1090 1100
 GCTGATGAAAAGCTTCGAAAGAAATCATCTTCTATCAATCATACCTCAG

 1110 1120 1130 1140 1150
 ACGCACACAATCAATGGGAATACAACCTGGACCAGAGGATAATTGTTATGT

 1160 1170 1180 1190 1200
 TTATGGTTGCCGGGGAAAGGAGGCAGTGGACAACCTTTCATCTCGGTGAT

 1210 1220 1230 1240 1250
 GACATGGACCCAGAGCTTCGTAGCCTGGCTCAGATCCTGATTGACCAGAA

 1260 1270 1280 1290
 AGTAAAAGAAATCTCGAACCAGGAACCTTTGAAACTCTAA

2. A recombinant expression plasmid containing the Seoul virus R22 nucleocapsid gene according to claim 1.
3. The recombinant expression plasmid according to claim 2, which is the expression plasmid pET-sNP constructed by cloning the Seoul virus R22 nucleocapsid gene of claim 1 into vector pET-3a.
4. A transformed *Escherichia coli* with the recombinant expression plasmid according to claim 2.
5. The transformed microorganism according to claim 4, which is the transformed *E. coli* BL(pET-sNP) produced by introducing the expression plasmid of claim 3 into *E. coli* BL21(DE3).
6. A fused form of Seoul virus R22 nucleocapsid protein having the following amino acid sequence isolated and purified from culture of the transformed

microorganism of claim 4:

```

      10      20      30      40      50
      |      |      |      |      |
MASNTGGQQMGRGSMATMEEIQREISAHEGQLVIARQKVKDAEKQYEKDP
      |      |      |      |      |
      60      70      80      90     100
      |      |      |      |      |
10  DDFNKRALHDRESVAASIQSKI DELKRLADRIAAGKNI GQDRDPTGVPEP
      |      |      |      |      |
      110     120     130     140     150
      |      |      |      |      |
      GDHLKERSALSYGNTLDLNSLDIDEPTGQTADWLTII VYLTSPFVVLII LK
      |      |      |      |      |
      160     170     180     190     200
      |      |      |      |      |
20  ALYMLTTRGRQTSKDNKGMRIRFKDDSSYEDVNGIRKPKHLYVSMNPNAQS
      |      |      |      |      |
      210     220     230     240     250
      |      |      |      |      |
      SMKAEETTPGRFRTAVCGLYPAQIKARNMVSPVMSVVGFLALAKDWTSR I
      |      |      |      |      |
      260     270     280     290     300
      |      |      |      |      |
30  EEWLGAPCKFMAESP IAGSLSGNPVNRNYIRQRQ GALAGMEPK EFQALRQ
      |      |      |      |      |
      310     320     330     340     350
      |      |      |      |      |
      HAKDAGCTLVEHIESPSSIWVFAGAPDRCPPTCLFVGGMAELGAFFSILQ
      |      |      |      |      |
      360     370     380     390     400
      |      |      |      |      |
40  DMRNTIMASKTVGTADEKLKKSSFYQSYLRRTQSMGTQLDQR IIVMFV
      |      |      |      |      |
      410     420     430     440
      |      |      |      |
      AWGKEAVDNFHLGDDMDPELRS LAQILIDQKVKEISNQEPLKL

```

7. A pharmaceutical composition for diagnosis of HFRS comprising the fused
 50 form of Seoul virus R22 nucleocapsid protein of claim 6.

8. A vaccine for prevention of HFRS comprising the fused form of Seoul virus R22 nucleocapsid protein of claim 6.

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FIG. 1

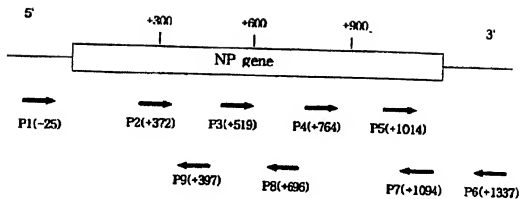


FIG. 2

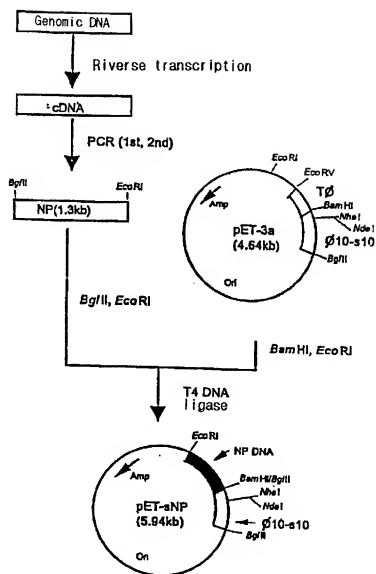
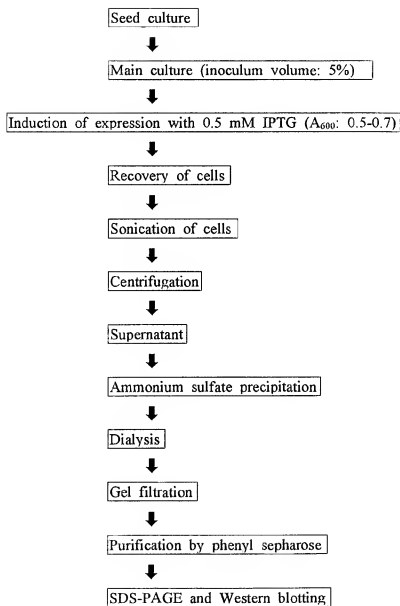
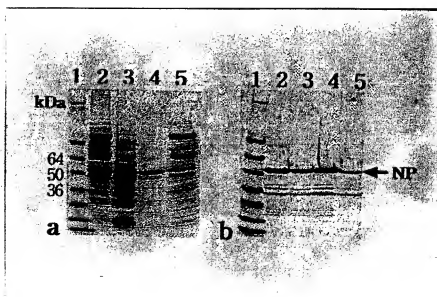


FIG. 3



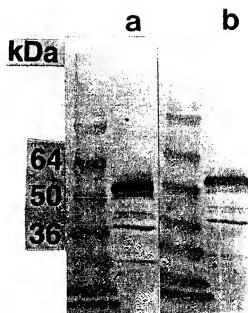
4/7

FIG. 4



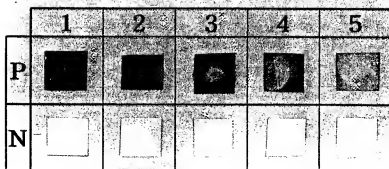
5/7

FIG. 5



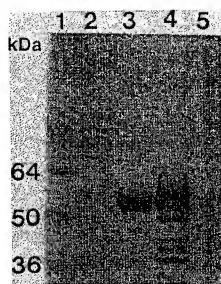
6/7

FIG. 6



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FIG. 7



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR 97/00184

A. CLASSIFICATION OF SUBJECT MATTER

IPC⁶: C 12 N 15/33; A 61 K 38/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC⁶: C 12 N 15/33; A 61 K 38/16

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	THE JOURNAL OF GENERAL VIROLOGY, Vol.74, April 1993, W. WANG et al.: "Expression of non-conserved regions of the S genome segments of three hantaviruses: evaluation of the expressed polypeptides for diagnosis of haemorrhagic fever with renal syndrome", pages 1115-1124, totality.	1-4
A	Database WPIL on Questel, week 01, London, Derwent Publications Ltd., AN 96-008501, KR 9402012 B1, abstract.	1

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

12 December 1997 (12.12.97)

Date of mailing of the international search report

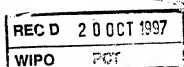
05 January 1998 (05.01.98)

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 Facsimile No. 1/53424/535

Authorized officer

Wolf

Telephone No. 1/53424/436



BUDAPEST TREATY ON THE INTERNATIONAL
RECOGNITION OF THE DEPOSIT OF MICROORGANISMS
FOR THE PURPOSES OF PATENT PROCEDURE

INTERNATIONAL FORM

To. CHEILJEDANG Corporation
12F CHEIL BLDG, 500,5GA,
NAMDAEMOON-NO, CHUNG-KU,
SEOUL, 100-095 KOREA

RECEIPT IN THE CASE OF AN ORIGINAL
issued pursuant to Rule 7.1 by the
INTERNATIONAL DEPOSITARY AUTHORITY
identified at the bottom of this page

I. IDENTIFICATION OF THE MICROORGANISM	
Identification reference given by the DEPOSITOR : E. coli BL(pETSNP)	Accession number given by the INTERNATIONAL DEPOSITARY AUTHORITY : KCCM - 10111
II. SCIENTIFIC DESCRIPTION AND/OR PROPOSED TAXONOMIC DESIGNATION	
<p>The microorganism identified under I above was accompanied by:</p> <p><input type="checkbox"/> a scientific description</p> <p><input type="checkbox"/> a proposed taxonomic designation</p> <p>(Mark with a cross where applicable)</p>	
III. RECEIPT AND ACCEPTANCE	
<p>the microorganism identified under I above was received by this international Depositary Authority on Sep. 16, 1996 and a request to convert the original deposit to a deposit under the Budapest Treaty was received by it on Sep. 10, 1997.</p>	
IV. INTERNATIONAL DEPOSITARY AUTHORITY	
<p>Name: Korean Culture Center of Microorganisms</p> <p>Address: Department of Food Engineering College of Eng. Yonsei University Sodaemun-gu, Seoul 120-749 Korea</p>	<p>Signature(s) of person(s) having the power to represent the International Depositary Authority or of authorized official(s) :</p> <p>Date: Sep. 19, 1997</p> 